International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 8, Issue 4, Aug 2018, 71-82

OPTIMIZATION OF PROCESS PARAMETERS IN WEDM PROCESS ON TWO WORKPIECES OF MATERIALS HARDOX-400 AND HARDOX-500

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ABSTRACT

Wire-cut Electric Discharge Machining is used to cut conductive metals of any hardness or that are difficult or impossible to cut with traditional methods. The objective of the present work is to investigate the effects of the various WEDM process parameters on the machining quality and to obtain the optimal sets of process The Taguchi technique has been used to investigate the effects of the WEDM process parameters and subsequently to predict set of optimal parameters for optimum quality characteristics in high chromium tool steels. This procedure eliminates the need for repeated experiments and saves time. The machining parameters investigated are Peak current, T-on, T-off and Wire feed rate. A series of experiments are conducted using WEDM. An orthogonal array (L_9) has been used to conduct the experiments. The raw data and S/N analysis are employed to find the influence of selected parameters on MRR. An objective of the present work is to reveal the influence of four different process parameters Peak current, Pulse on time (T_{ON}), Pulse off time (T_{OFF}) and Wire feed rate on Material Removal Rate (MRR) of HARDOX-400 and HARDOX-500 material for cutting on WEDM.

KEYWORDS: Taguchi Method, WEDM, Material Removing Rate, HARDOX-400 & HARDOX-500

Received: Apr 24, 2018; **Accepted:** May 14, 2018**; Published:** Jun 19, 2018; **Paper Id.:** IJMPERDAUG20189

Original Article

INTRODUCTION

In this growing world of technology, design, and manufacturing we need more accurate and defect free deliverables like product, service, design and technology. With the development of mechanical industry, the demands for alloy materials having high hardness, toughness, and impact resistance is increasing. Wire-cut Electric Discharge Machining is used to cut conductive metals of any hardness or that are difficult or impossible to cut with traditional methods. This machine also specializes in cutting complex contours or fragile geometries that would be difficult to be produced using conventional cutting methods. Machine tool industry has made exponential growth in its manufacturing capabilities in last decade but still, machine tools are not utilized at their full potential. This limitation is a result of the failure to run the machine tools at their optimum operating conditions. The problem of arriving at the optimum levels of the operating parameters has attracted the attention of the researchers and practicing engineers for a very long time. The objectives of the present of the various WEDM process parameters on the machining quality and to obtain the optimal sets of process parameters so that the quality of machined parts can be optimized. The working ranges and levels of the WEDM process parameters are found using one factor at a time approach. Work is to investigate the effects.

The Taguchi technique has been used to investigate the effects of the WEDM process parameters and subsequently to predict set of optimal parameters for optimum quality characteristics in high chromium tool steels. This research outlines the Taguchi's parameter design approach, which has been applied to optimize machining parameters during the machining process. This procedure eliminates the need for repeated experiments and saves time. The machining parameters investigated are T-on, T-off, Peak Current and Wire Feed. A series of experiments are conducted using WEDM. An orthogonal array (L9) has been used to conduct the experiments. The raw data and S/N analysis are employed to find the influence of selected parameters on MRR.

"WIRE EDM IS AN EXAMPLE OF CNC MACHINE"

LITERATURE SURVEY

The wire-cut type of machine arose in the 1960s for the purpose of making tools (dies) from hardened steel. The tool electrode in wire EDM is simply a wire. To avoid the erosion of material from the wire causing it to break, the wire is wound between two spools so that the active part of the wire is constantly changing. The earliest numerical controlled (NC) machines were conversions of punched-tape vertical milling machines. The first commercially available NC machine built as a wire-cut EDM machine was manufactured in the USSR in 1967. Machines that could optically follow lines on a master drawing were developed by David H. Dulebohn's group in the 1960s at Andrew Engineering Company for milling and grinding machines. Master drawings were later produced by computer numerical controlled (CNC) plotters for greater accuracy. A wire-cut EDM machine using the CNC drawing plotter and optical line follower techniques was produced in 1974. Dulebohn later used the same plotter CNC program to directly control the EDM machine, and the first CNC EDM machine was produced in 1976.

Past Research Work on WEDM

Sahandilya. P, Jain. P. K. &Jain. N. K [1] investigated made to considering the effect of voltage, pulse-on time, pulse-off time and wire feed rate on MRR and kerf in WEDM of SiCp/6061. Effect of input process parameters shows that maximum value of MRR and the minimum value of kerf are obtained at the lower level of voltage, lower level of pulse-on time. D. Satishkumar& M. Kanthababu & V. Vajjiravelu [2] investigated WEDM of Al/SiCp MMCs in various volume fractions (5%, 10% and 15% of SiC) prepared through stir casting process considering MRR and Ra as outputs. And they concluded the microstructure of stir cast composite shows discrete localized pool/agglomeration of SiC particles indicating constrain of the process for attaining uniform microstructure. Rajesh Kumar Bhuyan, B. C. Routara, Arun Kumar Parida, A. K. Sahoo [3] investigate the effect of process parameters such as pulse on time(Ton), peak current (Ip) and flushing pressure (Fp), metal removal rate (MRR), tool wear rate (TWR) and surface roughness (SR) during electrical discharge machining (EDM) of Al-SiC12% MMC.

The experiment is followed by Central composite design (CCD) method under different combination of process parameters. K. Zakaria, Z. Ismaila, N. Redzuana and K. W. Dalgarno [4] investigate the effect of wire EDM cutting parameters for evaluating of Additive Manufacturing Hybrid Metal Material. Hybrid metal materials produce through Additive Manufacturing of Indirect Selective Laser Sintering. It high light those important parameters to be considered in wire cutting process of FeCuSn hybrid metal material produce by Additive Manufacturing of Indirect Selective Laser Sintering process for fabricating the near net shape metal component. RavindranadhBobbili, V. Madhu, A. K. Gogia [5] investigates wire-EDM process parameters of the ballistic grade aluminum alloy.

EXPERIMENTAL PROCEDURE

Design of Experiments

The design of experiments (DOE, DOX, or experimental design) is the design of any task that aims to describe or explain the variation of information under conditions that are hypothesized to reflect the variation. The term is generally associated with true experiments in which the design introduces conditions that directly affect the variation, but may also refer to the design of experiments, in which natural conditions that influence the variation are selected for observation.

In its simplest form, an experiment aims at predicting the outcome by introducing a change of the preconditions, which is reflected in a variable called the predictor (independent). The change in the predictor is generally hypothesized to result in a change in the second variable, hence called the outcome (dependent) variable. Experimental design involves not only the selection of suitable predictors and outcomes but planning the delivery of the experiment under statistically optimal conditions given the constraints of available resources.

Main concerns in the experimental design include the establishment of validity, reliability, and replicability. For example, these concerns can be partially addressed by carefully choosing the predictor, reducing the risk of measurement error, and ensuring that the documentation of the method is sufficiently detailed. Related concerns include achieving appropriate levels of statistical power and sensitivity.

Correctly designed experiments advance knowledge in the natural and social sciences and engineering. Other applications include marketing and policymaking.

Taguchi Method

Taguchi methods are statistical methods, or sometimes called robust design methods, developed by Genichi Taguchi to improve the quality of manufactured goods, and more recently also applied to engineer biotechnology, marketing, and advertising. Professional statisticians have welcomed the goals and improvements brought about by Taguchi methods, particularly by Taguchi's development of designs for studying variation but have criticized the inefficiency of some of Taguchi's proposals.

Taguchi's work includes three principal contributions to statistics:

- The philosophy of off-line quality control and
- Innovations in the design of experiments.
- Loss functions in the statistical theory

ANOVA

Analysis of variance (ANOVA) is a collection of statistical models used to analyze the differences among group means and their associated procedures (such as "variation" among and between groups), developed by statistician and evolutionary biologist Ronald Fisher. In the ANOVA setting, the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form, ANOVA provides a statistical test of whether or not the means of several groups are equal, and therefore generalizes the t-test to more than two groups. ANOVAs are useful for comparing (testing) three or more means (groups or variables) for statistical significance. It is conceptually similar to multiple two-sample t-tests, but is more conservative (results in less type I error) and is therefore

suited to a wide range of practical problems.

Experimental Set-up, Process Parameter Selection and Experimentation

Work Piece Material

HARDOX-400

Table 1: Chemical Composition of HARDOX-400

C	Si	Mn	P	S	Cr	Mo	Ni
0.13	0.24	1.35	.009	.005	.41	.06	.054

HARDOX-500

Table 2: Chemical Composition of HARDOX-500

C	Si	Mn	P	S	Cr	Mo	Ni
129	**.226**	**.702**	**.005**	**.005**	**.631**	**.024**	**.047**

Preparation of Work Piece Specimen

Two workpieces of materials HARDOX-400 and HARDOX-500 of dimensions 150x60x20 mm are considered and a 4 square profile of 20x20 mm are being cut using wire EDM machine.

EXPERIMENTATION

The experiments have been conducted on the SPRING CUT WEDM. A diffused brass wire of 0.25 mm diameter is used as the cutting tool. D2 tool steel is a high carbon high chromium alloy and HARDOX are used as the specimen. The specimen is of rectangular shape having a thickness of 14 mm. The deionized water is used as dielectric and its temp. is kept at 20ºC. The three input process parameters namely peak current (IP), pulse-on time (TON), pulse-off time (TOFF), wire feed (WF). Following steps have been carried out in cutting operation.

- The wire is made to cut vertically with the help of verticality block.
- The workpiece is mounted and clamped on the work table with the help of bolts.
- A reference point on the workpiece is set for setting work coordinate system (WCS).

The programming has been done with the reference to the WCS. The reference point has been defined by the ground edges of the workpiece. The program is made for cutting operation of the workpiece and a profile of 20 mm x 20 mm square has been cut.

Selection of Variables: The variables selected are T-on, T-off, IP, and WF.

Selection of Levels: The levels selected are 3 for each of the variable.

Selection of Orthogonal Array: As three variables are considered in the present work and each having three levels, and the degree of freedom associated with one variable is 2 (Number of levels-1). So the degree of freedom associated with the three variables is 6. Hence, an orthogonal array having at least 6 DOF is to be selected. In the present work, the L9 OA is selected.

Table 3: Parameters at Different Level

S. No.	T-ON	T-OFF	IP	MRR
1	127	52	12	4.65
2	130	48	12	4.39
3	124	55	11	2.68
4	120	60	11	2.10
5	117	57	12	1.64
6	120	54	12	2.40
7	125	50	12	4.00
8	130	48	12	5.77
9	115	60	12	1.35

Figure 1: HARDOX-400 Test Sample After CNC Operation

Figure 2: HARDOX-500 Test Sample After CNC Operation

CNC Program for Wire EDM Machining

- G71
- G9
- G27
- G40
- G50
- G90
- G75
- ; Wire Compensation Definitions
- D0=0
- D1=0.162
- E780
- ;#1.0 Cavity=1 RoughCut
- G0 X0 Y-20 U0 V0

- M0
- G42 D0 ;D0=0
- G1 X-10 Y-20
- G42 D1 ;D1=0.162
- G1 X-10 Y-10
- G1 X-10 Y-10
- G1 X-10 Y-30
- G1 X-10 Y-30
- G1 X-10 Y-19
- M0
- G42 D0 ;D0=0
- G1 X-9 Y-19
- G40
- M0
- E780
- ;#2.0 Cavity=2 RoughCut
- G0 X0 Y-50 U0 V0
- M0
- G42 D0 ;D0=0
- G1 X-10 Y-50
- G42 D1 ;D1=0.162
- G1 X-10 Y-40
- G1 X10 Y-40
- G1 X10 Y-60
- G1 X-10 Y-60
- G1 X-10 Y-49
- M0
- G42 D0;D0=0
- G1 X-9 Y-49

- G40
- M0
- E780
- ;#3.0 Cavity=3 RoughCut
- G0 X0 Y-80 U0 V0
- M0
- G42 D0 ;D0=0
- G1 X-10 Y-80
- G42 D1 ;D1=0.162
- G1 X-10 Y-70
- G1 X10 Y-70
- G1 X10 Y-90
- G1 X-10 Y-90
- G1 X-10 Y-79
- M0
- G42 D0 ;D0=0
- G1 X-9
- Y-79
- G40
- M0
- E780
- ;#4.0 Cavity=4 RoughCut
- G0 X0 Y-110 U0 V0
- M0
- G42 D0 ;D0=0
- G1 X-10 Y-110
- G42 D1 ;D1=0.162
- G1 X-10 Y-100
- G1 X10 Y-100

- G1 X10 Y-120
- G1 X-10 Y-120
- G1 X-10 Y-109
- M0
- G42 D0 ;D0=0
- G1 X-9 Y-109
- G40
- M0

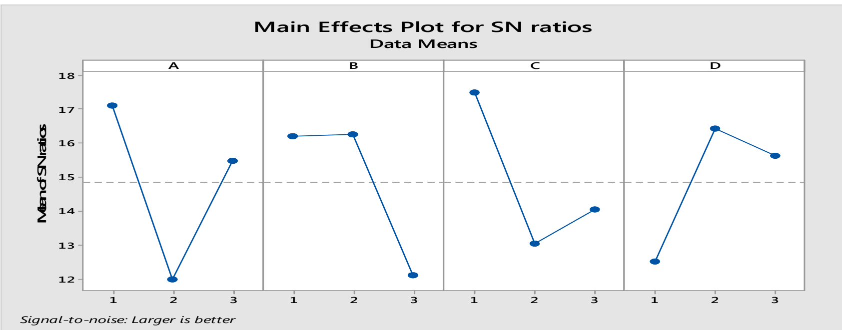
S/N Ratio Analysis

The S/N values are calculated with the help of software Minitab 17. The MRR value measured from the experiments and their corresponding S/N ratio values are listed in the given table:

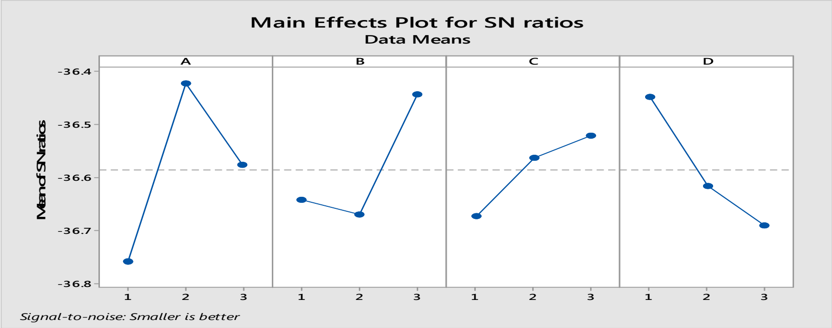
Table 4: S/N Ratios

S. No	S/N Ratio
1	18.7270
2	18.2881
3	14.3212
4	12.3031
5	10.2327
6	13.4446
7	17.5753
8	20.2833
9	8.5699

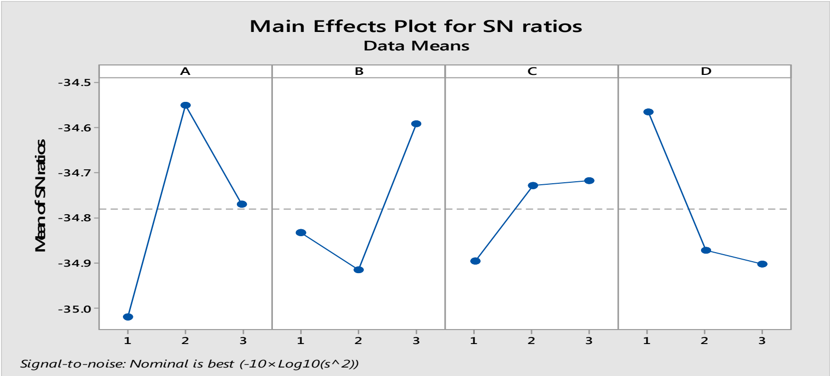
In the above table, signal-to-noise ratio approach to measuring the quality characteristic deviates from the desired value. S/N ratio is used as an objective function for optimizing parameters. Control factors are easily adjustable, and it is set by the manufacturer. These factors are most important in determining the quality characteristics.



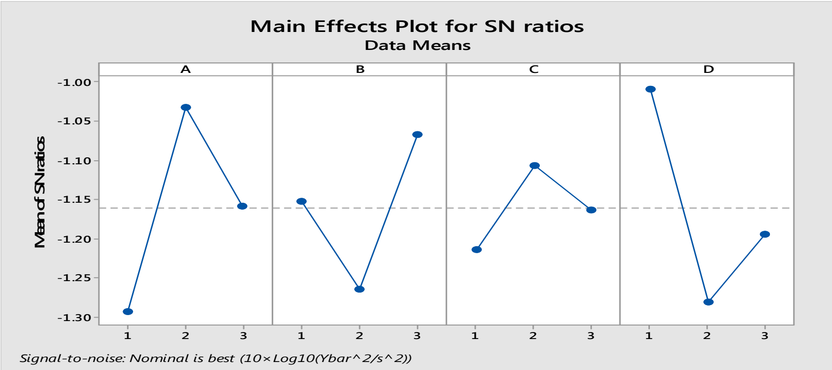
Graph 1: Main Effects plot for S/N Ratio (LARGER is Better)



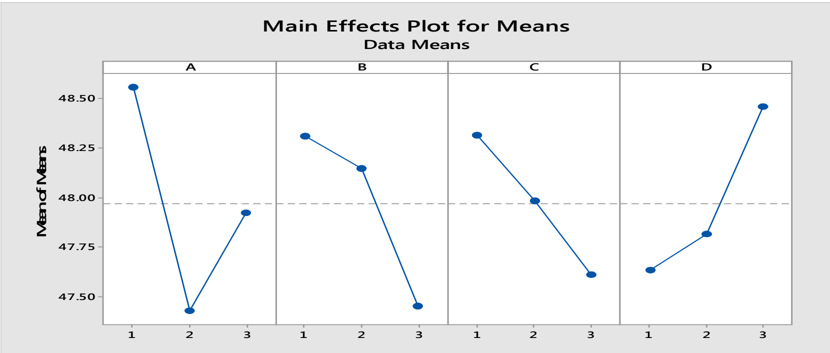
Graph 2: Main Effects Plot for S/N Ratio (Smaller is Better)



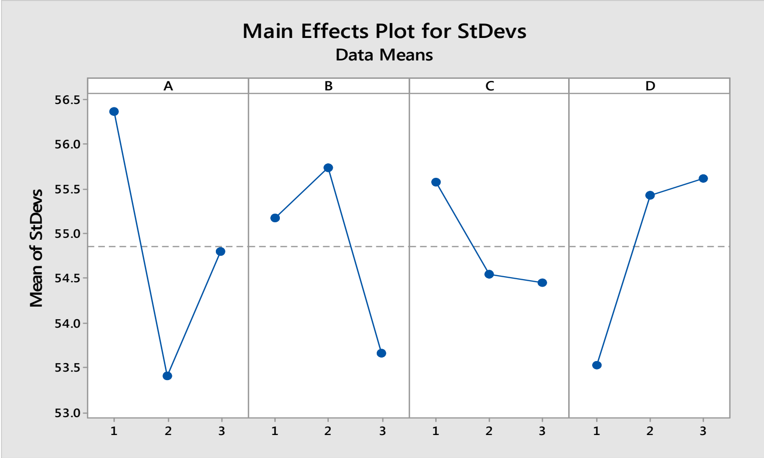
Graph 3: Main Effects Plot for S/N Ratio (Nominal is Best-1)



Graph 4: Main Effects Plot for S/N Ratio (Nominal is Best-2)



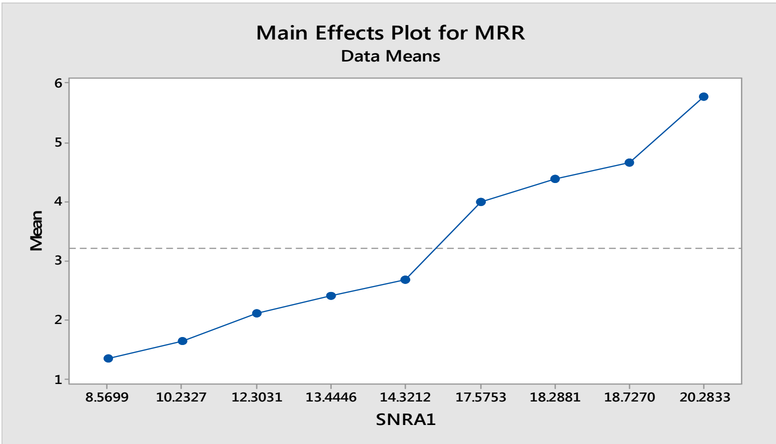
Graph 5: Main Effect Plot for Means



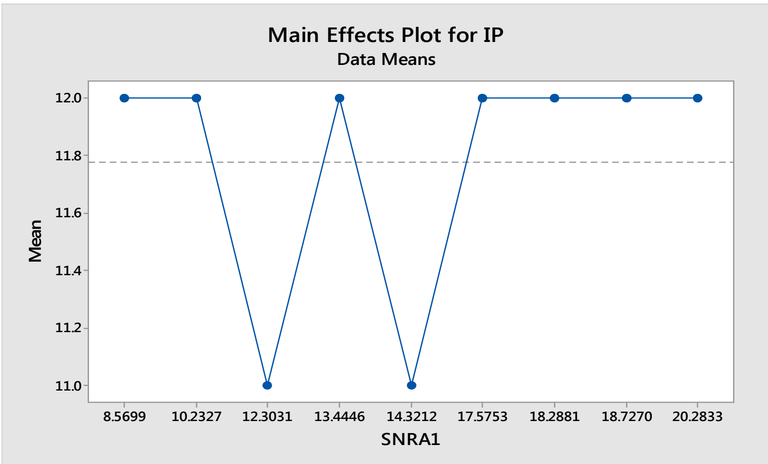
Graph 6: Main Effect Plot for StDevs

Analysis of Variance for S/N Ratio

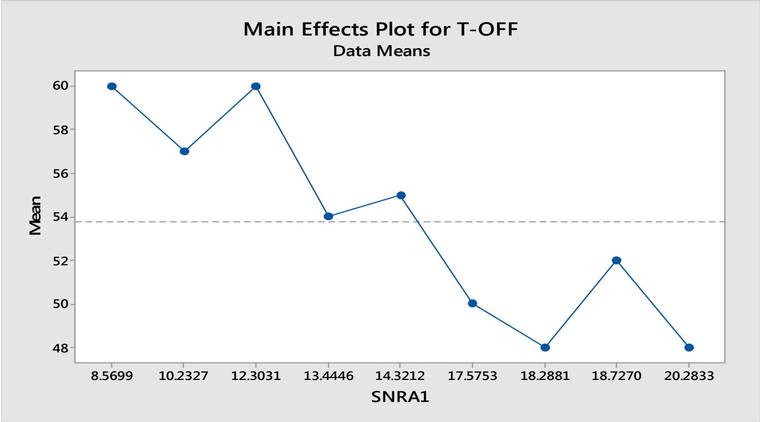
ANOVA results for MRR are given in table below.



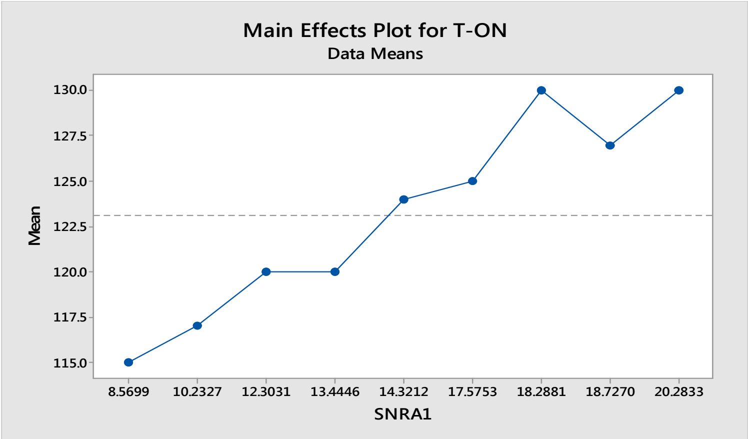
Graph 7: Main Effect Plot for MRR



Graph 8: Main Effect Plot for IP



Graph 9: Main Effect Plot for T-OFF



Graph 10: Main Effect Plot for T-ON

Confirmation Test Result

Regardless of the category of the performance characteristics, greater S/N value corresponds to a better performance. Therefore the optimum level of process parameters is the level with the greatest value of S/N ratio. The MRR increases with the increase in pulse on time and decreases with the increase in the pulse off time and spark gap set voltage. This is because the discharge energy increases with the pulse on time and peak current leading to a faster cutting rate. As the pulse off time decreases, the number of discharges within the given period becomes more which leads to a higher cutting rate. With increases in spark gap set voltage the voltage discharge gap gets widened resulting into a lower cutting rate and then suddenly starts increasing. It is also evident that cutting is minimum at first level of the pulse on time and maximum at first level of pulse off time.

After analyzing S/N graphs and mean plots for optimal conditions for the selected response variable (Material Removal Rate), it is found that the MRR increases with the increase in pulse on time, and decreases with increase in pulse off time and spark gap set voltage. This is because the discharge energy increases with the pulse on time and peak current leading to a faster cutting rate. As the pulse off time decreases, the number of discharges within a given period becomes more which leads to a higher cutting rate. With the increase in spark gap set voltage, the average discharge gap gets widened resulting into a lower cutting rate and then suddenly starts increasing. It is also evident that cutting rate is minimum at first level of the pulse on time and maximum at first level of pulse off time.

CONCLUSIONS

This confirmation test for the optimal parameter setting with its selected level was concluded to evaluate the quality characteristics for WEDM of HARDOX-400 and HARDOX-500. Experiment show the highest signal to noise ratio values, indicating the optimal process parameter set of Ton, Toff, IP; WF has the best values among the nine experiments which can be compared with the result of ANOVA for validation of result.

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